DECOMPOSITION OF RAPTOR PELLETS

by
James R. Philips
and
Daniel L. Dindal
Department of Forest Zoology
State University of New York
College of Environmental Science and Forestry
Syracuse, New York 13210

Abstract

Decomposing pellets from Great Horned Owls were studied during the summer and fall of 1973. After four months, pellets weighed 38–89 percent of their initial dry weight. Thirteen species of fungi were isolated from the pellets. Funnel extraction yielded 3,665 invertebrates from 75 pellets. The most important invertebrates in pellet decomposition appear to be the trogid beetles and the tineid moths. Raptor pellets serve as a feeding, breeding, and shelter site for many invertebrates, including predators, parasites, fungivores, and saprovores.

Introduction

Indigestible material is quite commonly regurgitated by birds in the form of roughly oval to cylindrical pellets. Such regurgitation is known to occur in 330 species in more than 60 families, according to a survey made by The International Bird Pellet Study Group (Glue 1973). Among them are such birds as jays, flycatchers and thrushes, as well as hawks and owls (Simmons 1973, Tucker 1944). Raptor pellets generally consist of fur, feathers, bone, scales, chitin, and other prey remains, densely packed and held together by mucus secreted from the digestive tract which dries and hardens soon after egestion. In some cases, pellets of wax (Honey Buzzard, *Pernis apivorus*, Meinertzhagen 1959) or even soil (Kestrel, *Falco tinnunculus*, Davis 1975) may be found. Pellets are also ejected by other vertebrates, including some mammals, reptiles, and amphibians (Hanson pers. comm., Dobroruka 1973).

Pellets provide data on avian food habits and prey populations, but many other aspects are of interest as well. Smith and Richmond (1972), Duke et al. (1973, 1975, 1976), and others have examined the physiology of pellet formation and regurgitation. Dobrokhotov and Litvin (1971) studied time-related dynamics of Kestrel pellet formation by measuring pellet radioactivity after the raptor ingested mice containing P^{32}. Raptor pellets may also play a role in the spread of diseases such as sylvatic plague, since they are temporarily infective if diseased prey has been eaten (Jellison 1939). Plague antigens can be detected much longer than the plague microbe itself in pellets, and pellet analysis has been proposed as one of the best methods of detecting epizootic plague infestations (Lobachev et al. 1971, Lobachev and Shenbrot 1974).

Pellet decomposition has been given very little attention. Some authors have reported that pellets may remain intact for many years (Brooks 1929, Prestt and Wagstaffe 1973). Others have found that pellets are broken down in weeks or months (Wilson 1938, Marti 1974). Watling (1962, 1963) studied fungal succession on Kestrel

Raptor Research 13(4):102–111

(*Falco tinnunculus*) pellets and isolated 51 species of fungi and one alga. Hubálek (1974) isolated many fungal species from owl pellets. The invertebrate fauna reported from pellets is limited to a few insects (table 1). Therefore, the objective of this research was to elucidate the invertebrate microcommunity associated with decomposition of owl pellets. The concept of microcommunity as presented by Dindal (1973a) was assumed in the study.

Table 1. Insect Fauna of Raptor Pellets

Order Family	References
Coleoptera	
Dermestidae Carpet beetles	Wallace, 1948
Dermestes spp.	Simmons, 1971
Silphidae Carrion beetles	Hanson, pers. comm.
Trogidae Skin beetles	Petersen, 1960
Trox erinaceous J. Lec.	Davis, 1909
Trox foveicollis Harold	Vaurie, 1955
Trox plicatus Robinson	Vaurie, 1955
Trox scaber (L.)	Davis, 1909
Trox spinulosus simi Robinson	Vaurie, 1955
Trox striatus Mels.	Vaurie, 1955
Trox variolatus Mels.	Dillon and Dillon, 1972; Vaurie, 1955
Diptera	
Anthomyiidae Anthomyid or latrine flies	
Fannia aerea (Zetterstedt)	Aubrook, 1939
Hydrotaea occulta (Meigen)	Aubrook, 1939
Scatophagidae Manure-feeding flies	
Scatophaga squalida Meigen	Aubrook, 1939
Scenopinidae Window flies	
Scenopinus sp.	de Joannis, 1899
Hymenoptera	
Braconidae Braconid parasitoid wasps	
Phaenocarpa ruficeps (von Es.)	Aubrook, 1939
Lepidoptera	
Tineidae Clothes moths	Morton et al., 1977; Vernon, 1972
Monopis ferruginella (Hubner)	Hinton, 1956
Monopis rusticella (Clerck)	Nurse, 1906; Buxton, 1914; Elton, 1966
Monopis weaverella Scott	Elton, 1966
Tinea pellionella (L.)	de Joannis, 1899
Tineola bisselliela (Hummel)	de Joannis, 1899
Trichophaga sp.	Moon, 1940
Trichophaga tapetzella (L.)	de Joannis, 1899; Forbes, 1923; Baer, 1924; Davis (cited by Lutz, 1948)

Methods

Rats (*Rattus norvegicus*) were fed to five Great Horned Owls (*Bubo virginianus*). Pellets and pellet fragments were collected as soon as possible after regurgitation. They were dried in an oven at 60°C for 24 hours. Dry weight and volume were

measured. The dry pellets were placed in 6-mm mesh nylon bags and frozen. On 3 July 1973, 90 "pellet bags" were set out in a maple-oak stand at our College's Forest Experiment Station, Lafayette Road, Syracuse, New York. The pellets varied in weight from 3.08 to 11.47 g (av. 6.06); length ranged from 33 to 86 mm (av. 49.71) and width, from 20 to 34 mm (av. 25.11).

Six pellets were removed every 8 days for 4 months. Five pellets were placed in modified Tullgren funnels for extraction of invertebrates. As the pellets air-dried, desiccation drove out the invertebrates, which fell into a collecting jar containing an alcohol and glycerin solution placed at the base of the funnel. The remaining pellet was used for culturing of fungi and invertebrates. Portions of the pellet were incubated on moist filter paper in a petri dish in the dark at 25°C. When insects hatched, they were preserved in alcohol. As fungal growth became evident, pieces of the pellet were transferred onto mycobiotic agar. The other half of the pellet was used for culturing of fungi by means of the soil-dilution agar plate method (Menzies 1965). Dilutions from 10^{-4} to 10^{-6} were used with preparations of mycobiotic and malt agars.

Results and Discussion

After 4 months' exposure to field conditions, pellets weighed from 38.03 to 89.53 percent of their initial dry weight, averaging 62.87 percent (fig. 1). Decomposition rates were highly variable because of differences in size, composition, microenvironment, and faunal and floral colonization of pellets.

Physical Factors. Weather is a major factor in pellet decomposition. Rain flattens the pellet, dissolves the mucus, washes hair away from bones near the surface of the pellet, and helps create entry holes for invertebrates. Freezing and thawing are also important (Wilson 1938).

Faunal Microcommunity. Fresh moist pellets attract flies, such as Calliphoridae and Anthomyiidae, which deposit their eggs on the pellets. Such flies do not appear to be attracted to dried or older pellets. Other flies may be found on older, moist pellets; however, pellets may at times represent islands of moisture on the soil litter surface and attract cryptozoans, such as sowbugs and earthworms. Snails and slugs can also be found on pellets, and the large slug *Limax maximus* often leaves a trail of mucus on pellets it has visited nocturnally. Various transient species, such as ants, centipedes, millipedes, and spiders, also visit pellets, as well as occasional hungry mammals (Wilson 1938, Fleay 1968) and industrious pack rats (Griffin 1976, Long and Kerfoot 1963). Pellets support large populations of protozoa and nematodes, and even tardigrades may be present.

Pellets serve as habitat for beetles such as Leptodiridae and Staphylinidae. Various parasitic wasps find pellets to be a source of hosts. Predatory, parasitic, fungivorous, and saprophagous mites all were found. Akimov and Shehur (1972) have shown that the acarid mites *Tyrophagus putrescentiae* (Schrank), *Glycyphagus domesticus* (Deg.), and *Rhizoglyphus echinopus* (Fum. et Rob.) cannot digest keratin but feed on the lipids associated with keratinous substances such as feathers. However, other possible food sources are present, on feathers and pellets. Also, we have often found larvae, nymphs, and adults of *T. putrescentiae,* on pellets, with alimentary tracts filled with hyphae and fungal spores.

The two most important pellet invertebrate decomposers are the tineid moths and

the trogid beetles. The larvae of the Tineidae, or clothes moths (fig. 2), eat hair and feathers, and we have found over 60 of them in a single pellet. Pellets sometimes appear to be covered ventrally with a centimeter or more of debris. Actually this is a thin layer of soil and moth excreta covering many cases of silk constructed by the larvae. These cases range from 7 to 18 mm long by 2 mm wide, and the larvae feed and pupate within them. The open end of the case is in the pellet and the case resembles a small "sock" sticking out of the pellet. In decomposed pellets, the silken network of these moth cases may be all that holds the remaining bones together. Fly larvae of the genus *Scenopinus* prey on tineid larvae in pellets (de Joannis 1899).

The trogid beetles also feed on hair and feathers, and their larvae burrow into the soil beneath the pellet. The burrows may be 30 mm deep by 2 mm wide, and they may be lined with hair for the upper 20 mm. Trogid beetles also serve as transportation for uropodine and macrochelid mites (Sixl 1971). Many mites attach themselves to insects for transportation from one site to another. This relationship is known as phoresy. A mesostigmatic mite *Macrocheles penicilliger* (B.) has been reported phoretic on *Trox scaber* in owl nests in England (fig. 3). We have found it on *Trox variolatus* in pellets and rat carrion in central New York. In addition we have found nematodes that are also phoretic on the phoretic *Macrocheles* mite (fig. 3). There are several other published records of this type of nematode phoresy (Dindal 1973b, Ramsay 1970).

Funnel extraction data for both tineid moths and trogid beetles was found to be unreliable because their cases provide considerable protection against desiccation. The trogid beetles are often found beneath the pellets—adults in the litter, and larvae in the soil. Millipedes, sowbugs, and earthworms were also observed on pellets more frequently than the extraction data indicates (table 2).

Perhaps the most surprising find was a specimen of *Radfordia*. This prostigmatic mite is a small mammal ectoparasite which feeds in the bases of hair follicles (Krantz 1971). The specimen was in good condition but was probably dead and accidentally fell into the collecting jar during extraction. However, another specimen was obtained in an extraction of fresh Great Horned Owl pellets. These findings bring up the question of whether ectoparasites may occasionally survive in the environment of a raptor's stomach long enough to be regurgitated alive in a pellet. Chmielewski (1970) studied the passage of astigmatic mites through the alimentary canal of mice, sparrows, and hens. Survival rates of some species varied from 1–7 percent. Survivors included individuals of all stages although eggs and resting stages were more resistant. Other parasites may also occasionally be found in pellets. Bond (1940) reported Great Horned Owl pellets in Nevada containing chicken ticks, *Argas persicus* (Oken); for example, one pellet contained a gopher skull and 42 ticks. Also, roundworms such as *Porrocaecum* and *Ascaridia* are sometimes egested with pellets (Cooper 1972). In addition to vertebrate parasites, we have periodically found insect and acarine parasites of other invertebrates on pellets.

Pellet Flora. Thirteen species of fungi were isolated from the pellets (table 3). Other species of fungi were observed on the pellets, but culture attempts failed. The most important species (as judged by visible growth) are *Trichoderma* sp. and *Chrysosporium tropicum* Carmichael. Large green patches of *Trichoderma* at times covered up to 20 percent of the pellet surface. Most pellets had some surface growth of *Chrysosporium,* and some appeared extremely white as the fungus took over as much as

Table 2. Invertebrates from Great Horned Owl Pellets

	no. pellets (75)	no. of specimens	max. no. on one pellet
Prostigmata	73	1,840	156
Collembola	55	884	84
Oribatei	63	369	57
Mesostigmata	53	241	42
Lepidoptera	43	194	22
Astigmata	18	27	6
Coleoptera	14	26	9
Hymenoptera	9	17	6
Gastropoda	9	13	2
Diptera	7	12	2
Isopoda	9	11	2
Homoptera	8	8	1
Araneida	7	8	2
Chilopoda	3	4	2
Thysanoptera	2	4	3
Psocoptera	3	3	1
Diplopoda	1	1	1
Oligochaeta	1	1	1
Pauropoda	1	1	1
Symphyla	1	1	1
Total		3,665	

Av. no./pellet	48.87	Mites	67.59%
Av. no./g dry wt	9.25	Insects	31.32%
Max. no./g dry wt on one pellet	48.00	Others	1.09%

Table 3. Fungi from Great Horned Owl Pellets

Alternaria sp.
**Aspergillus flavus* Link
Aspergillus fumigatus Fresenius
**Aspergillus niger* Van Tieghem
Aspergillus sp.
Chaetomium sp.
Chrysosporium tropicum Carmichael
**Fusarium roseum* section
Paecilomyces sp.
Rhizopus sp.
Sporotrichum sp.
Trichoderma sp.

* species not previously reported from pellets

75 percent of the surface (fig. 4). *Chrysosporium* is a keratinophilic fungus which attacks hair with the aid of penetrating bodies (Carmichael 1962). This genus is common on bird feathers and in their nests (Pugh 1966, 1972; Pugh and Evans 1970; Otcenášek et al. 1967; Rees 1967; Hubálek 1974. While *Aspergillus fumigatus,* the cause of aspergillosis in birds, was found, its occurrence in pellets does not appear to be an unusual source of infection since the fungus is so widespread.

Summary

Pellets may serve as a site of breeding, feeding, and shelter for many invertebrates and as a substrate for growth of a variety of fungi. Some invertebrates consume various pellet components such as the lipids of hair and feathers while others feed on the fungi. Still other predatory or parasitoid invertebrates are attracted to pellets where they afflict some of the "pioneer" invertebrates.

Pellets may be found in many habitats. They are produced by many avian and other vertebrate species, and they differ widely in composition depending upon the prey species. For these reasons pellets are excellent instructional tools since they illustrate so many aspects of ecology. Much remains to be learned about pellets as habitats for microbe and invertebrate microcommunities.

Acknowledgments

We thank Jack Gray for allowing us to use two of the owls of the Burnet Park Zoo, Syracuse, and Dr. A. A. Padhye of the Center for Disease Control, Atlanta, Georgia, for identifying the fungi. Also, Dr. Roy A. Norton graciously aided in the identification of the mite species we collected.

Literature Cited

Akimov, E. A., and L. E. Shehur. 1972. Features of the nutrition of the grain mites *Glycyphagus domesticus* (Deg.) and *Tyrophagus putrescentiae* (Schr.) and the root mite *Rhizoglyphus echinopus* (Fum. et Rob.) on some proteinoids. (In Russian, English summary). *Vestnik Zool.* 6(6):45–48.

Aubrook, E. W. 1939. Insects bred from owl pellets. *Entomol. Mon. Mag.* 75:88.

Baer, W. 1924. Biologische Beobachtungen an Kleidermotten. *Naturw. Korresp.* 2:122–123.

Bond, R. M. 1940. Food habits of horned owls in the Pahranagat Valley, Nevada. *Condor* 42(3):164–165.

Brooks, A. 1929. On pellets of hawks and owls. *Condor* 31:222–223.

Buxton, P. A. 1914. Habit of *Tinea rusticella. Entomol. Rec.* 26:143.

Carmichael, J. W. 1962. *Chrysosporium* and some other aleuriosporic hyphomycetes. *Canadian J. Bot.* 40:1137–1174.

Chmielewski, W. 1970. The passage of mites through the alimentary canal of vertebrates. *Ekol. Pol. Ser. A.* 18(35):741–756.

Cooper, J. E. 1972. Hawks and parasites. *Hawk Chalk* 11:31–35.

Davis, T. A. W. 1975. Food of the kestrel in winter and early spring. *Bird Study* 22(2):85–91.

Davis, W. T. 1909. Owl pellets and insects. *J. New York Entomol. Soc.* 17(2):49–51.

Dillon, E. S., and L. S. Dillon. 1961. *A manual of common beetles of Eastern North America.* Dover Publications, New York. 2 vols. 894 pp.

Dindal, D. L. 1973a. Microcommunities defined. Pages 2–6 in D. L. Dindal (ed.), *Soil Microcommunities I,* Proc. First Conf. Nat. Tech. Information Serv. USAEC. CONF-711076, Springfield, Virginia.

Dindal, D. L. 1973b. Review of symbiotic relationships in soil invertebrates. Pages 227–256 in D. L. Dindal (ed.), *Soil Microcommunities I.,* Proc. First Conf. Nat. Tech. Information Serv. USAEC. CONF-711076, Springfield, Virginia.

Dobrokhotov, B. P., and V. Yu. Litvin. 1971. Radioactivity of pellets of *Falco tinnunculus* L. after feeding on mice containing P^{32}. (In Russian, English summary). *Zool. Zh.* 50:1591–1592.

Dobroruka, L. J. 1973. Pellet formation in the Japanese giant salamander. *Int. Zoo. Yrbk.* 13:158.

Duke, G. E., J. C. Ciganek, and O. A. Evanson. 1973. Food consumption and energy, water and nitrogen budgets in captive Great Horned Owls (*Bubo virginianus*). *Comp. Biochem. Physiol.* 44(A):283–292.

Duke, G. E., O. A. Evanson, and A. Jegers. 1976. Meal to pellet intervals in 14 species of captive raptors. *Comp. Biochem. Physiol.* 53(A):1–6.

Duke, G. E., A. A. Jegers, G. Loff, and O. A. Evanson. 1975. Gastric digestion in some raptors. *Comp. Biochem. Physiol.* 50(A):649–656.

Elton, C. S. 1966. *The pattern of animal communities.* Wiley, New York. 432 pp.

Fleay, D. 1968. *Nightwatchmen of bush and plain.* Taplinger, New York. 163 pp.

Forbes, W. T. M. 1923. *The Lepidoptera of New York and neighboring states.* Primitive forms, Microlepidoptera, Pyraloids, Bombyces. Mem. Cornell Agric. Exp. Sta. No. 68. 729 pp.

Glue, D. E. 1973. Owl pellets. Pages 193–197 in J. A. Burton (ed.), *Owls of the world.* E. P. Dutton, New York.

Griffin, C. R. 1976. A preliminary comparison of Texas and Arizona Harris' Hawks (*Parabuteo unicinctus*) populations. *Raptor Res.* 10(2):50–54.

Hinton, H. E. 1956. The larvae of the species of Tineidae of economic importance. *Bull. Entomol. Res.* 47:251–346.

Hubálek, Z. 1974. The distribution patterns of fungi in free-living birds. *Acta Sc. Nat. Brno* 8(9):1–51.

Jellison, W. L. 1939. Sylvatic plague: Studies of predatory and scavenger birds in relation to its epidemiology. U.S. Public Health Service. *Public Health Reports* 54:792–798.

Joannis, J. de. 1899. Note sur quelques Microlepidoptères dont les chenilles se nourissent de poils d'animaux. *Bull. Soc. Entomol. Fr.* 1899:248–250.

Krantz, G. W. 1971. *A manual of acarology.* Oregon State Univ. Book Stores, Inc., Corvallis, Oregon. 335 pp.

Lobachev, V. S., M. E. Levi, and M. M. Levschitz. 1971. The preservation of a specific antigen of a plague-causing agent in the food pellets of predatory birds. (In Russian, English summary). *Zool. Zh.* 50:1593–1595.

Lobachev, V. S., and G. Shenbrot. 1974. Food of the Little Owl in the North Aral Sea area. (In Russian). *Ornitologiya* 11:382–390.

Long, C. A., and W. C. Kerfoot. 1963. Mammalian remains from owl-pellets in eastern Wyoming. *J. Mammal.* 44(1):129–131.

Lutz, F. E. 1948. *Field book of insects.* G. P. Putnam's Sons, New York. 510 pp.

Marti, C. D. 1974. Feeding ecology of four sympatric owls. *Condor* 76(1):45–61.

Meinertzhagen, R. 1959. *Pirates and predators.* Oliver and Boyd, London. 230 pp.
Menzies, J. D. 1965. Fungi. Pages 1502–1505 in C. A. Black (ed.), *Methods of soil analysis.* Part 2. Am. Soc. Agronomy Inc., Madison, Wisconsin.
Moon, E. L. 1940. Notes on hawk and owl pellet formation and identification. *Trans. Kansas Acad. Sci.* 43:457–466.
Morton, S. R., M. Happold, A. K. Lee, and R. E. MacMillan. 1977. The diet of the barn owl, *Tyto alba,* in southwestern Queensland. *Australian Wildl. Res.* 4:91–97.
Nurse, C. G. 1906. Food of *Monopis rusticella. Entomologist* 39:160.
Otcenášek, M., K. Hudec, Z. Hubálek, and J. Dvorák. 1967. Keratinophilic fungi from the nests of birds in Czechoslovakia. *Sabouradia* 5:350–354.
Peterson, A. 1960. *Larvae of insects.* Part 2. Edwards Bros., Ann Arbor, Michigan. 416 pp.
Prestt, I., and R. Wagstaffe. 1973. Barn and bay owls. Pages 42–60 in J. A. Burton, (ed.), *Owls of the world.* E. P. Dutton, New York.
Pugh, G. J. F. 1966. Associations between birds' nests, their pH, and keratinophilic fungi. *Sabouradia* 5:49–53.
_____. 1972. The contamination of birds' feathers by fungi. *Ibis* 114:172–177.
Pugh, G. J. F., and M. D. Evans. 1970. Keratinophilic fungi associated with birds. I. Fungi isolated from feathers, nests, and soils. *Trans. British Mycol. Soc.* 54(2):233–240.
Ramsay, G. W. 1970. Mites with phoretic nematodes. *New Zealand Entomol.* 4(4):91–92.
Rees, R. G. 1967. Keratinophilic fungi from Queensland. II. Isolation from feathers of wild birds. *Sabouradia* 6:14–18.
Simmons, G. E. 1971. Patterns of life in woodland communities. 8. Bird pellets. *Quarterly J. Forestry.* 65:224–231.
_____ 1973. The study of bird pellets. *Country Side* 22:116–122.
Sixl, W. 1971. Ein Beitrag zur Kenntnis der Phoresie. *Mitt. naturwiss. Ver. Steiermark.* 100:405–406.
Smith, C. R., and M. E. Richmond. 1972. Factors influencing pellet egestion and gastric pH in the Barn Owl. *Wilson Bull.* 84:179–186.
Tucker, B. W. 1944. The ejection of pellets by passerine and other birds. *British Birds* 38:50–52.
Vaurie, P. 1955. A revision of the genus *Trox* in North America (Coleoptera, Scarabaeidae). *Bull. American Mus. Nat. Hist.* 106(1):1–89.
Vernon, C. J. 1972. An analysis of owl pellets collected in southern Africa. *Ostrich* 43:109–124.
Wallace, G. J. 1948. *The Barn Owl in Michigan.* Its distribution, natural history and food habits. Michigan State Coll. Agric. Exp. Sta. Tech. Bull. 208. 61 pp.
Watling, R. 1962. Fungal succession on kestrel pellets. *Naturalist* 41–43.
Watling, R. 1963. The fungal succession on hawk pellets. *Trans. British Mycol. Soc.* 46(1):81–90.
Wilson, K. A. 1938. Owl studies at Ann Arbor, Michigan. *Auk* 55:187–197.

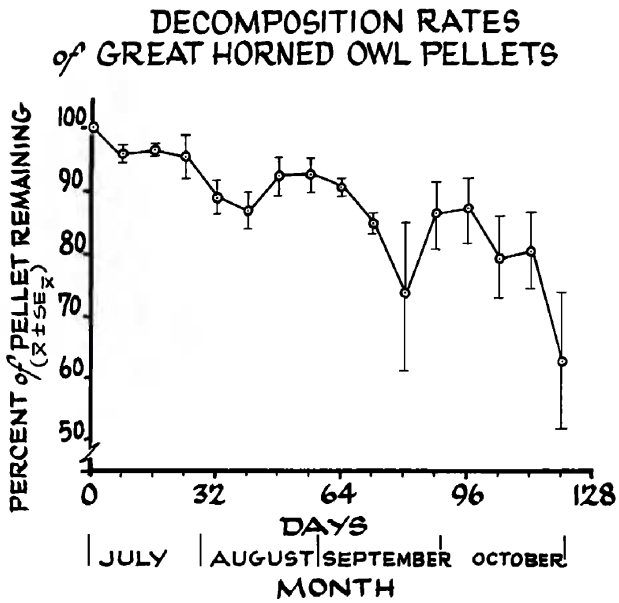

Figure 1. Decomposition rate of Great Horned Owl pellets.

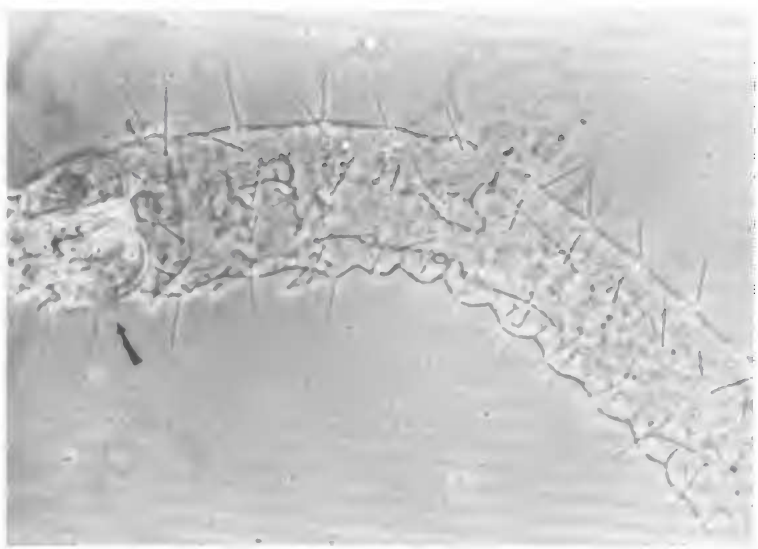

Figure 2. Larva of clothes moth, Tineidae (head capsule indicated by arrow).

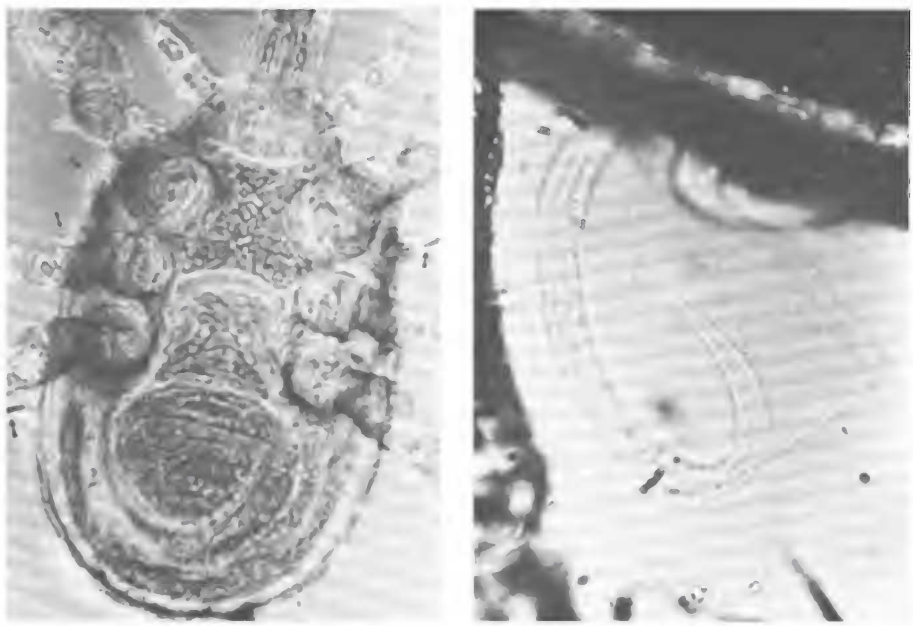

Figure 3. Phoretic nematodes (indicated by arrows) attached to mesostigmatic mite *Macrocheles penicilliger*.

Figure 4. Growth of the white keratinophilic fungus, *Chrysosporium tropicum*, on surface of decomposing Great Horned Owl pellet.